Management Measure 10
Existing Development

A. Management Measure

Develop and implement watershed management programs to reduce runoff pollutant concentrations and volumes from existing development and redevelopment:

- Identify opportunities to reduce pollutants in priority local and/or regional watersheds (e.g., improvements to existing urban runoff control structures, including the addition of infiltration, filtration, retention, and detention to runoff patterns).
- Devise a schedule for implementing appropriate controls.
- Limit destruction of natural conveyance systems.
- Where appropriate, preserve, enhance, or establish buffers along surface waterbodies and their tributaries.
- Promote redevelopment by assessing previously contaminated soils.

B. Management Measure Description and Selection

1. Description

The purpose of this management measure is to protect or improve surface water quality by developing and implementing watershed management programs that pursue the following objectives:

- Reduce surface water runoff pollution loadings from areas where development has already occurred.
- Limit the volume of surface water runoff to minimize sediment loading from erosion of streambanks and other natural conveyance systems.
- Preserve, enhance, or establish buffers that provide water quality benefits along waterbodies and their tributaries.

Maintaining water quality becomes increasingly difficult as urbanization occurs and areas of impervious surface increase. Increased peak runoff volumes from impervious surfaces result in alteration of stream channels, natural drainageways, and riparian habitat. This alteration in turn results in elimination or reduction of predevelopment aquatic flora and fauna and degradation of predevelopment water quality. Other effects include increased bank cutting, streambed scouring, siltation, increases in water temperature, decreases in dissolved oxygen, and changes to the natural structure and flow of the stream or river.

Protecting water quality in urbanized areas is difficult because of many factors. These factors include diverse pollutant loadings, large runoff volumes, limited areas suitable for surface water runoff treatment systems, the high implementation costs associated with structural controls, and the destruction or absence of buffer zones that can filter pollutants and prevent the destabilization of streambanks and shorelines.

An important nonstructural component of many watershed management plans is the establishment and preservation of buffers and natural systems (e.g., by policy, code, or ordinance). These areas help to maintain and improve surface water quality by filtering and infiltrating urban runoff. In areas of existing development, natural buffers and conveyance systems might have been altered as urbanization occurred. Where possible and appropriate, additional impacts on these areas should be minimized, and if the areas are degraded, their functions should be restored. Establishing and protecting buffers is most appropriate along surface waterbodies and their tributaries, where water quality and the biological integrity of the waterbody are dependent on the presence of an adequate buffer or riparian area. Buffers might be necessary where the buffer or riparian area

- Reduces significant nonpoint source pollutant loadings.
- Provides habitat necessary to maintain the biological integrity of the receiving water.
- Reduces undesirable thermal impacts on the waterbody.

Where existing development precludes the use of effective nonstructural controls, structural practices might be the only suitable option to decrease the nonpoint source pollution loads generated from developed areas. In such situations, a watershed plan can be used to integrate the construction of new surface water runoff treatment structures and to retrofit existing surface water runoff management systems.

Retrofitting is a process that involves the modification of existing surface water runoff control structures or surface water runoff conveyance systems that were initially designed to control flooding, not to serve a water quality improvement function. By enlarging existing surface water runoff structures, changing the inflow and outflow characteristics of such devices, and increasing runoff detention and retention time, sediment and associated pollutants can be removed from the runoff. Retrofit of structural controls is often the only feasible alternative for improving water quality in developed areas. Where existing development or financial constraints limit treatment options, targeting—identifying priority pollutants and selecting the most appropriate retrofits that will result in the greatest improvement to water quality—might be necessary.

Once key pollutants have been identified, an achievable water quality target for the receiving water should be set to improve current levels based on an identified objective or to prevent degradation of current water quality. Extensive site evaluations should then be performed to assess the performance of existing surface water runoff management systems and to pinpoint low-cost structural changes or maintenance programs for improving pollutant-removal efficiency. Where flooding problems exist, source controls, low-impact development (LID), and infiltrative controls should be incorporated into the design of surface water runoff controls.

Available land area is often limited in urban areas, and the lack of suitable areas frequently restricts the use of conventional pond systems. In heavily urbanized areas, sand filters, bio-filters, or water quality inlets with oil/grit separators might be appropriate for retrofits because they do not limit use of the land.

2. Management Measure Selection

The first and second components of this management measure were selected to encourage communities to develop and implement watershed management programs. Local conditions, availability of funding, and problem pollutants vary widely among developed communities. Watershed management programs allow these communities to select and implement the practices that best address local needs. Identifying priority local and/or regional pollutant reduction opportunities and setting schedules for implementing appropriate controls were selected as logical starting points in the process of establishing an institutional framework to address nonpoint source pollutant reduction.

The third and fourth components of this management measure were selected to preserve, enhance, and establish areas within existing development that provide positive water quality benefits such as natural streams, ponds, and wetlands and aquatic buffers. These natural systems provide efficient runoff conveyance, as well as wildlife and aesthetic benefits. The fifth component was selected to encourage redevelopment of underused or contaminated sites in urban areas to improve soil, surface water, and ground water quality at those sites and to preserve undeveloped green spaces that could provide a water quality benefit. Also, In January of 2002, the Small Business Liability Relief and Brownfields Revitalization Act was signed into law (USEPA, 2002b). This act greatly expands the brownfields program and specifies the following changes to the program:

- Provides legislative authority for the brownfields program including grants for assessment and cleanup.
- Expands the current brownfields program by increasing its funding authority up to $200 million per year including up to $50 million per year to assess and clean up brownfields with petroleum contamination.
- Expands eligibility for assessment and cleanup grants.
- Includes a new provision for direct cleanup grants of up to $200,000 per site.
- Streamlines current requirements for the brownfields cleanup revolving loan fund and makes funding available to nonprofit organizations.
- Applies the Davis Bacon Act on the same terms as the authority for the current program.
- Makes funds available for technical assistance, training, and research.

More information about the Small Business Liability Relief and Brownfields Revitalization Act can be found at *www.epa.gov/brownfields/sblrbra.htm*.

Cost was a major factor in the selection of this management measure. EPA acknowledges the following constraints to implementing nonpoint source controls for existing development:

- High costs and other limitations inherent in treating existing sources to levels consistent with the standards set for developing areas.

- Frequent lack of suitable areas for structural treatment systems that can adequately protect receiving waters.

- Lack of universal cost-effective treatment options.

- Frequent lack of funding for mandatory retrofitting.

- Extraordinarily high costs associated with implementing retention ponds and exfiltration systems in developed areas.

C. Management Practices

1. Identify, Prioritize, and Schedule Retrofit Opportunities

In the watershed assessment phase of the urban runoff management cycle, watershed managers should identify waterbodies that have been degraded by urban runoff and require restoration. One method to halt further degradation and initiate waterbody recovery is to retrofit existing runoff management practices or conveyance structures. It is important for watershed managers to have clear goals and realistic expectations for retrofitting existing structures. Each retrofitting project should be planned in the context of a comprehensive watershed plan, and managers should have a clear set of objectives for each retrofit project to ensure that the project results in measurable improvements in hydrologic, habitat, and/or water quality indicators.

a. Evaluate existing data

The first step in identifying candidate sites for storm water retrofitting is to examine existing data. These data can include results from a watershed assessment, topographic maps, land use or zoning maps, property ownership maps, aerial photos, and maps of the existing drainage network. For example, results from a watershed assessment can be used to identify areas with good habitat and water quality that should be protected and areas with poor habitat and water quality that need to be improved. Topographic maps can be used to delineate drainage units within the watershed at the subwatershed and catchment levels. Land use or zoning maps can be used to estimate areas of high impervious cover to target areas that contribute a large amount of runoff to receiving waters, while property maps provide land ownership data. Finally, aerial photographs can be used to identify open spaces that can be more easily developed into runoff management facilities. According to the Center for Watershed Protection (CWP, 1995a), the best retrofit sites

- Are located adjacent to existing channels or at the outfall of storm drainage pipes.
- Are located within an existing open area.
- Have sufficient runoff storage capacity.
- Are feasible for diverting runoff to a potential facility.
- Have a sufficient drainage area to contribute meaningfully to catchment water quality.

Specific areas well suited for new runoff controls include undeveloped parkland and open space areas, golf courses, wide floodplains, highway rights-of-way, and parking lot edges.

Information for potential retrofit sites, such as location, ownership, approximate drainage area, utility locations, and other pertinent details, can be compiled in a retrofit inventory sheet (CWP, 1995a). A site visit can provide information on site constraints, topography, adjacent sensitive land uses, receiving water conditions, utility crossings, and other considerations that would affect the feasibility of management practice implementation. At this point, a conceptual sketch for the management practice for each site should be drawn and preliminary cost estimates made.

b. Choose appropriate management practices based on site conditions

The choice of one potential retrofit site over another for management practice implementation can be based on several different factors in addition to site limitations and cost. For instance, a retrofit program might be targeted to preserve streams or reaches known to have high-quality habitat or exceptional water quality. The goal of another program might be to restore poor habitat and degraded water quality. The program might target particular land uses thought to contribute the majority of pollutants to receiving waters. Retrofit facilities can also be installed to treat runoff that drains the largest area of the subwatershed, thereby requiring fewer overall projects. Once retrofit sites are identified and prioritized, a schedule for installing new facilities or updating old facilities should be devised.

c. Incorporate low impact development practices into existing development

In many cases, sites that are already developed can be retrofitted with low impact development practices such as biofilters, rainbarrels, rooftop greening, and planting urban trees in buffers in urban areas (see Management Measure 5 for a more detailed discussion of these practices). All of these practices can be designed on a small scale to accommodate space constraints that may be present on already-developed sites. They will aid in retaining runoff on-site and reducing the total volume of runoff reaching receiving waters. The *Low-Impact Development Design Strategies: An Integrated Design Approach* (Prince George's County, Maryland, Department of Environmental Resources, 2000) and the Low Impact Development Center web site (*www.lowimpactdevelopment.org*) can provide more information about these and other practices appropriate for existing developments. Additionally, a search for "urban forestry" on the USDA Forest Service's web site (*www.fs.fed.us*) produces many good references about how trees can be used to reduce runoff volume and improve runoff quality

Case Study: Retrofitting Catch Basins for On-Street Runoff Storage

An example of a retrofit to reduce downstream impacts of urbanization can be found in the towns of Skokie and Wilmette, Illinois. These towns are urban areas that are served by a combined sewer system (CSS). Both communities wanted to control CSS surcharge but did not want to build expensive relief sewers. As a result, they were willing to try alternative approaches. The towns decided to modify street cross sections and storm drain inlets to allow runoff to be stored temporarily on the street surface during storm events to reduce hydraulic loading to CSSs. The street surface storage projects combined the following elements (USEPA, 2000b):

- Street storage.
- Downspout disconnection.
- Flow regulators.
- Subsurface storage.
- New storm and combined sewer systems.
- Improvements to existing storm and combined sewer systems.

The projects involved installing a system of street berms, 7 to 9 inches high, at the curb line to detain water on the street. Flow regulation devices were installed at catch basin outlets to reduce the rate of storm water flow to the CSS. Both the street surface and the inlet structure were used for storage. Subsurface storage facilities were also installed in the street right-of-way and in other public areas at critical points in the system and in pedestrian walkways, parking areas, and high-traffic areas, where ponding was unacceptable.

The project resulted in a number of benefits. Researchers estimated a cost savings from using street storage rather than conventional sewer separation systems. Estimated costs for the Skokie system are approximately 38 percent of conventional sewer separation system costs. Berm costs are a small fraction of the overall cost of the CSS surcharge relief project. Another benefit of the storage system is traffic control. Berms can function as speed humps and help control traffic. The street storage system also reduces the volume and frequency of combined sewer overflows, resulting in less runoff-related pollution entering receiving waters. Icing of ponded areas during the winter was not a problem because retention times were relatively short (less than 30 minutes).

2. Implement Retrofit Projects as Scheduled

CWP (1995b) describes six common types of retrofitting projects:

- Modifying existing runoff management facilities.
- Constructing new management practices at the upstream end of road culverts.
- Constructing new management practices at storm drainage pipe outfalls.
- Constructing small in-stream practices in channels.
- Constructing on-site measures at the edge of large parking areas.
- Constructing new management practices in highway rights-of-way.

a. Retrofit existing runoff management facilities

Many older dry detention basins were designed for the singular purpose of flood control. In some cases, a facility of this type can be converted into an extended detention pond/wetland or a conventional wet pond. If this retrofit is designed well, it will increase pollutant removal capabilities and aquatic habitat functions without losing any of its flood control benefits. This modification also typically results in only minimal impacts on the surrounding environment. The retrofit process often includes the following:

- Analyzing existing hydraulic characteristics and the flood control design specifications of the facility.
- Determining whether there is available storage for water quality treatment.
- If water quality storage is available, usually excavating the pond bottom to create permanent pool storage (for pond and wetland systems).
- If extended detention is needed, raising the embankment or modifying the outlet structure to obtain additional storage.
- To increase particulate settlement, increasing the flow path from inflow point to discharge point by using baffles or earthen berms or by regrading the pond's contours.

b. Modify the upstream end of road culverts

A good retrofit opportunity can sometimes be found at the upstream end of a road culvert. A gabion, concrete weir structure, or riser/barrel control structure could be installed to create a small, permanent micropool excavated to provide water storage, water quality, and habitat

Case Study: Cost-Effectiveness Study of Retrofitting Runoff Treatment Facilities

EPA's Office of Research and Development investigated retrofitting wet-weather flow treatment facilities to determine their feasibility and cost-effectiveness (Moffa et al., 2000). The following retrofit scenarios were analyzed:

- Converting or retrofitting primary settling tanks with dissolved air flotation and lamellae (thin, flat membranes or layers) and/or microsand-enhanced plate or tube settling units.
- Retrofitting existing wet-weather flow storage tanks to provide enhanced settling/treatment and post-storm solids removal.
- Converting dry ponds to wet ponds for enhanced treatment.
- Retrofitting wet-weather flow storage tanks for dry-weather flow augmentation.
- Using storage for sanitary sewer overflow control.
- Retrofitting for industrial wastewater control in a combined sewer system.
- Bringing outdated/abandoned treatment plants back on-line as wet-weather flow treatment facilities.

The cost-benefit analysis examined site-specific, operational, cost, and design parameters. Each retrofit scenario was analyzed over a range of flow and/or volume conditions. The study revealed that in certain circumstances, retrofitting existing wet-weather flow treatment facilities is technically feasible and can be more cost-effective than construction of new conventional control and treatment facilities. The authors concluded that these results were highly site-specific and recommended that retrofitting existing control facilities be identified as one of several alternatives to reduce impacts from storm events. The full report is available at the Office of Research and Development's web site at *www.epa.gov/ednnrmrl/news/main.htm*.

benefits. This method can be used to provide a dry extended detention basin with a maximum depth of 6 feet above the culvert invert. If the upstream area is open floodplain, it might be possible to construct a wet pond or extended detention pond/wetland retrofit.

Because roadways are not originally constructed as runoff management embankments, however, special measures might be necessary to ensure that these facilities meet dam safety specifications for seepage control and passage of the 100-year storm. Consideration and evaluation of secondary impacts, such as modification of the 100-year floodplain, creation of fish migration barriers, and changes to the wetland hydrologic regime is also warranted with this type of retrofit.

c. Modify storm drainage pipe outfalls

A volume of runoff can be diverted at or near a storm drainage pipe outfall to a sand filter, peat-sand (or other medium) filter, bioretention system, centrifugal deflection system, off-line wetland or pond system, or other water quality treatment facility for treatment before it enters a receiving water.

d. Add retention structures to channelized streams

Small weir walls or check dams can sometimes be placed in small, previously channelized streams to retain sediments and create a ponding area for wetland vegetation. This type of retrofit is usually easy to install and can provide moderate pollutant removal benefits. Because it can potentially affect channel design flows and the floodplain, however, careful analysis must be conducted before the in-stream practice is implemented.

e. Install runoff management practices in or adjacent to large parking areas

Retrofit practices can be installed near large parking lots to capture, detain, and/or treat runoff. Infiltration practices like bioretention areas, porous pavement, sand filters, and underground vaults are good candidates. Two examples of successful use of bioretention areas can be found at *www.epa.gov/owow/nps/bioretention.pdf* (USEPA, 2000a). In addition, a case study illustrating the effectiveness of porous pavement in reducing runoff is provided at *www.epa.gov/owow/nps/pavements.pdf* (USEPA, 2000b).

f. Construct new practices in highway rights-of-way

Existing highway systems can have significant open spaces for the installation of various practices. For example, cloverleaf open space can be an ideal location for storm water wetlands and pond systems if drainage areas and patterns allow. Care must be taken to avoid creating a safety hazard for traffic, and maintenance access should be an integral part of the design.

g. Install trash-capturing devices

Trash racks are inclined metal grates that trap floatables as water passes through. The racks can be installed at storm sewer inlets or outfalls or in the stream itself. These structures effectively remove trash from the water, but they require a high level of maintenance (inspection for damage after storm events and regular trash removal). If these racks are poorly maintained, their effectiveness decreases and they can clog, which can cause a flood hazard. A less-expensive alternative to metal trash racks is plastic mesh trash collectors with floating piers that stretch across the width of the stream. They are easier to maintain because they are simply removed and replaced with a new collector.

The applicability of these trash collection methods is limited to small streams with relatively low flow and low-level trash inputs. More substantial trash collection methods, such as vortex devices that use centrifugal force to separate floatables from water, can be installed to handle larger flows or high trash loads.

h. Install inlet and grate inserts

A wide variety of inserts are also commercially available that trap oil and grease from parking lots, maintenance yards, and streets. These can be used with or without trash capture in storm drain inlets and grates. Inspection and maintenance 1 to 4 times per year (depending on pollutant concentrations in runoff) is usually recommended.

3. Restore and Limit the Destruction of Natural Runoff Conveyance Systems

Existing development has likely resulted in a modification of natural drainage patterns as compared to predevelopment conditions. These modifications are manifested in increases in imperviousness, runoff, peak flows during storm events, erosion, and pollutant transport, which results in greater downstream impacts. These modifications resulted from the prevalence of traditional runoff management techniques that involved rapidly transporting runoff off-site by means of curbs and pipes.

Efforts should be made to restore previously developed or redeveloping sites so they more closely mimic predevelopment hydrologic conditions. The predevelopment condition should be estimated based on historical records and existing slopes, soils, and natural drainage features. Consideration should be given to the time of concentration—the time it takes water to travel from the farthest point in a subwatershed to the outlet. (Sites might contain multiple subwatersheds and multiple outlets.) Paving and curbing substantially reduce time of concentration, resulting in high peak flows during storm events. Time of concentration can be increased substantially by modifying drainage patterns and installing infiltration and detention practices. The practices presented in this section can be used to increase time of concentration on a particular site. Additional technical guidance for restoration practices can be found at EPA's River Corridor and Wetland Restoration web site at www.epa.gov/owow/wetlands/restore (USEPA, 2002a). Another resource is *Stream Corridor Restoration: Principles, Processes, and Practices* (FISRWG, 1998), which can be downloaded at www.usda.gov/stream_restoration/newgra.html or ordered by contacting the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161; telephone 703-605-6000 or 800-553-NTIS; e-mail orders@ntis.fedworld.gov.

a. Disconnect impervious areas

Roof downspouts can be disconnected from streets and culverts and runoff diverted over vegetation or into rain barrels for reuse (see Management Measure 5 for more information on rain barrels). Also, roadway runoff can be converted to sheet flow and directed to vegetated buffers, infiltration devices, or other pervious areas.

Rooftop runoff also can be controlled with a vegetated roof cover. These systems consist of a high-quality waterproof membrane covered by drainage material, a planting medium, and vegetation. Vegetated roof covers use foliage and a lightweight soil mixture to absorb, filter, and detain rainfall. The systems are designed to control high-intensity storms by intercepting and retaining water until the rainfall peak passes (USEPA, 2000d). Additionally, vegetated roof covers improve insulation and reduce the amount of reflected solar radiation, resulting in lower temperatures in urban areas. More information about vegetated roof covers can be found at www.*epa.gov/owow/nps/ roofcover.pdf*.

b. Encourage overland sheet flow

Concentrated flow of runoff during storm events results in decreased time of concentration, decreased infiltration, and increased erosion due to high runoff velocity. Careful regrading to reduce steep slopes slows runoff, promotes infiltration, and reduces erosion. A level spreader, which typically consists of a shallow, gravel-filled trench that receives concentrated flows and converts them to sheet flow, can be installed to convey runoff to vegetated areas. A flat, grassy area can also be used to promote overland flow.

c. Increase flow path

Increasing the path of runoff results in increased storm water detention and increased travel time. Directing concentrated flows from impervious areas to infiltration areas, swales, dry wells, cisterns, or bioretention facilities increases the time it takes for runoff to leave the site and mitigates peak runoff flows.

d. Use open swales in place of traditional storm drain systems

Grassed swales are an effective and natural means of conveying runoff. Because the water comes into contact with vegetation, the runoff velocity decreases, which promotes infiltration, reduces erosion, and lengthens time of concentration. Because grassed swales are wider and shallower than conventional channels, runoff is less concentrated. They are especially appropriate alongside roadways or on the border of a site. Swales can be combined with terraces and infiltration devices to enhance runoff retention. Swale installation requires a minimum amount of excavating and regrading. Vegetation should be established immediately to prevent excessive erosion; while vegetation is being established, geotextiles or turf reinforcement mats can be used to stabilize exposed soils in the swale.

e. Establish vegetation throughout the site

Vegetation intercepts rainfall, decreases runoff velocity by increasing surface roughness, and promotes infiltration. Establishing vegetated areas in strategic locations that currently receive runoff from impervious areas requires minimal effort, especially when native plant species are used. Excess compaction of these areas by heavy equipment should be avoided. To enhance the benefits of vegetated areas, part of a site can be regraded during redevelopment activities to direct runoff to these areas.

Case Study: Restoration in the Anacostia River Watershed

The Anacostia River has been cited nationally as exemplifying urban watershed problems (AWRC, 1998). These problems are typified by

- Conversion of natural drainage networks into man-made channels.
- Increased runoff and urban pollutants from impervious surfaces.
- Channel erosion and associated loss of aquatic habitat from changes in land use.
- Sediments laden with toxic substances and other pollutants from motor vehicles.
- Electrical transformers, past applications of persistent pesticides, poorly timed applications of fertilizers, combined sewer overflows, atmospheric deposition, and pet waste.
- Thousands of tons of trash and debris.

As a result of this degradation, in 1987 a concerted effort to restore and protect the Anacostia watershed was initiated in the form of the Anacostia Watershed Restoration Agreement and the establishment of the Anacostia Watershed Restoration Committee (AWRC), which involved the District of Columbia, Montgomery and Prince George's counties in Maryland, the State of Maryland, the U.S. Army Corps of Engineers, the Metropolitan Washington Council of Governments, and the Interstate Commission on the Potomac River Basin. The cooperative effort was expanded in 1996 with the creation of the AWRC's Anacostia Watershed Citizens Advisory Committee (AWCAC). The AWCAC has brought formal recognition of the importance and need for citizen input and involvement in the restoration.

The AWRC established a framework to guide long-term restoration efforts and identified 580 restoration projects to correct existing environmental problems and enhance overall ecosystem quality. As of 1997 approximately $20 million had been spent on implementing roughly 29 percent of the 580 identified projects, with additional millions of dollars spent on planning, design, land acquisition, and maintenance. An additional $54 million had been spent on engineering controls designed to reduce the impacts of combined sewer overflows on the tidal river and of leaking, aging sewer lines on tributary streams. As a result of the restoration efforts, the submerged aquatic vegetation once absent from the river is beginning to reappear, signaling some improvement in water clarity, as the volume and concentrations of pollutants from urban runoff have been reduced. The successes have required the identification of problems and associated solutions, coordination of programs, and the mobilization of critical government, political, and financial resources. Key features in the success of the Anacostia program have been the development of common watershed restoration goals and the identification and establishment of partnerships.

More information about the Anacostia Watershed Restoration Project can be found at *www.anacostia.net*.

f. Reestablish ground water recharge

Traditional development techniques that focus on quickly conveying runoff off-site have resulted in decreased infiltration of rainfall to ground water. This ground water deficit results in a lowered water table and decreased seepage and baseflow in streams during dry periods. Infiltration practices can be installed to promote ground water recharge. Such practices include infiltration trenches, infiltration basins, sand filters, biofiltration systems, and vegetated areas underlain by permeable soils.

Case Study: A Watershed Restoration Plan for the Norwalk River Watershed

Habitat quality and water quality in the Norwalk River watershed of southeastern Connecticut have been degraded by erosion, sediment, pesticides, excessive algae growth, driftwood and other impoundments, and other types of pollution associated with increased watershed urbanization (NWRI, 1998). In 1997 federal, state, and local government agencies, environmental groups, and concerned citizens formed the Norwalk River Watershed Initiative (NRWI) to halt further degradation and promote water quality recovery. Subcommittees were tasked with developing goals for four key issues: (1) habitat restoration; (2) land use, flood protection, and open space; (3) water quality; and (4) stewardship and education.

The NWRI assessed existing water quality and riparian conditions based on data collected by the Connecticut Department of Environmental Protection, U.S. Geologic Survey, and U.S. Department of Agriculture. They also identified land uses that contribute to water quality problems, areas where stream channels had been modified by dams or flood control projects, and point sources such as municipal wastewater treatment facilities.

Based on the results of the assessment, the NWRI developed the Norwalk River Watershed Action Plan, which describes specific objectives and action items to accomplish those objectives for each of the four key areas listed above. Each objective contains a list of specific tasks with the implementing group clearly identified, the proposed time line for each task, and a measure of the tasks' success. The NWRI also developed an outreach program to foster stewardship and to educate watershed residents about the impacts of daily activities that contribute to the degradation of the Norwalk River watershed.

For more information on the Watershed Action Plan or to obtain a copy of the plan, contact the Norwalk River Watershed Coordinator, Connecticut Department of Environmental Protection, Bureau of Water Management, 79 Elm Street, Hartford, CT 06106; telephone 860-424-3096; e-mail tessa.gutowski@po.state.ct.us.

g. Protect sensitive areas

Areas that should be considered for preservation and restoration at sites with existing development include riparian areas, 100-year floodplains, wetlands, woodlands and valuable trees, and areas with permeable soils. Steep slopes and erosive soils should be protected and stabilized to the extent possible.

4. Restore Natural Streams

Restoration design for streams degraded by prior urbanization should consider preexisting conditions and their effects on restoration objectives. Eight restoration tools can be applied to help restore urban streams. These tools are intended to compensate for stream functions and processes that have been diminished or degraded by prior watershed urbanization. Best results are usually obtained when the tools are applied together; otherwise, the same sources that degraded the stream remain unchanged, causing similar effects.

A resource for information about restoring natural streams is *Stream Corridor Restoration: Principles, Processes, and Practices* (FISRWG, 2000), which is available for purchase or download at www.usda.gov/stream_restoration/newgra.html. Another resource is *Urban Stream Restoration: A Video Tour of Ecological Restoration Techniques* (Riley, 1998b), which is available for purchase at www.noltemedia.com/nm/urbanstream/index2.html.

a. Partially restore the predevelopment hydrologic regime

The primary objective of storm water management is to reduce the frequency of bankfull flows in the contributing watershed. This is often done by constructing upstream storm water retrofit ponds that capture and detain increased storm water runoff for up to 24 hours before release (i.e., extended detention). A common design storm for extended detention is the 1-year, 24-hour storm event. Storm water retrofit ponds are often critical in the restoration of small and mid-sized streams, but they might be impractical in larger streams and rivers.

b. Reduce urban pollutant pulses

A second need in urban stream restoration is to reduce concentrations of nutrients, bacteria, and toxics in the stream, as well as trapping excess sediment loads. Generally, three tools can be applied to reduce pollutant inputs to an urban stream: storm water ponds or wetlands (see Management Measure 5), watershed pollution prevention programs (see Management Measure 9), and the elimination of illicit discharges or improper connections to the storm sewer network (see Management Measure 9).

c. Stabilize channel morphology

Over time, urban stream channels enlarge their dimensions and are subject to severe bank and bed erosion. Therefore, it is important to stabilize the channel and, if possible, restore equilibrium to the channel geometry. In addition, it is useful to provide undercuts or overhead cover to improve fish habitat. Depending on the stream order, the impervious cover in the watershed, and the height and angle of eroded banks, a series of different tools can be applied to stabilize the channel and prevent further erosion. Bank stabilization measures include revegetated riprap and soil bioengineering methods (see Management Measure 7) such as willow stakes, brush bundles, bio-logs, lunker structures, and rootwads.

Case Study: Restoring Channel Morphology in a North Carolina Stream

Long Leaf Creek is located in an urbanized watershed along coastal North Carolina (Sotir, 2000). The stream had deepened and widened as a result of increased runoff and high concentration events, including hurricanes. This change reduced aesthetic value, damaged riparian vegetation and aquatic and terrestrial habitats, and degraded water quality. Managers selected a soil bioengineering approach over other alternatives after considering such issues as erosion control, streambank stabilization, safer and healthier environment, flood control, timely project completion, environmental and aesthetic improvement, property loss minimization, hydraulic efficiency, and cost feasibility. They installed live fascines, brush layer/live fascine combinations, joint planting, and vegetated geogrids.

The survival rates of the live vegetation ranged from 60 to 80 percent depending on the species used; maintenance proved to be a key factor in survival rates. Several important needs were identified, including studying bed conditions in areas that have had high deposits of mobile materials, employing sophisticated grade control structures, following installation procedures and maintenance schedules, and encouraging communication and cooperation between engineers and wetland scientists.

Case Study: Restoring Atlanta's Watersheds

The International Life Sciences Institute's Risk Science Institute (RSI) was tasked with assessing the condition of streams in Atlanta, Georgia; developing a watershed management implementation plan; and identifying specific watershed restoration activities that would improve riparian habitat and water quality in four example subwatersheds (RSI, 1998). They identified several habitat and water quality impacts that can be attributed to urbanization, including

- Increased magnitude and frequency of bankfull and subbankfull events.
- Stream channel dimensions out of equilibrium with hydrologic regime.
- Enlarged, highly modified channels.
- Increased sediment load due to upstream channel erosion.
- Decreased baseflow.
- Decreased wetted perimeter.
- Degraded in-stream habitat structure.
- Reduced large woody debris.
- Increased number of stream crossings, which are potential barriers to fish migration.
- Fragmentation and narrowing of riparian forests.
- Degraded water quality.
- Increased summer stream temperatures.
- Reduced aquatic diversity.
- Combined sewer overflows.

To address these issues, RSI developed a watershed management program for the Atlanta region that includes the following elements:

- Creation of an institutional framework for watershed management (Management Measure 1).
- Development of a comprehensive storm and surface water control program.
- Establishment of erosion and sediment control programs.
- Establishment of detention pond requirements.
- Expansion of the tree canopy.
- Management of buffers, sensitive areas, and floodplains.
- Establishment of land development provisions.
- Daylighting of streams.
- Relocation of utilities.
- Eradication of invasive and exotic species.
- Development of a public education and outreach campaign.

RSI also developed several objectives for the watershed management program and identified environmental indicators that can be used to gauge the effectiveness of management activities (see Management Measure 2). Finally, RSI examined four subwatersheds to identify specific management practices that can be used to fulfill the objectives of the watershed management program. In each case study, they identified the activities in the subwatershed that were contributing to resource degradation and suggested methods, such as separating storm and sanitary sewers and improving storm water infiltration, that would reduce runoff to prevent further waterbody degradation. These methods would also increase the effectiveness of in-stream and riparian restoration activities. RSI then identified site-specific restoration activities such as streambank stabilization, riparian buffer management, and creation or restoration of in-stream habitat.

For more information about the Watershed Management Program for Atlanta or to receive a copy of RSI's report, contact the Risk Science Institute, International Life Sciences Institute, 1126 16th Street, NW, Washington, DC 20036-4810; e-mail rsi@ilsi.org.

d. Restore in-stream habitat structure

Most urban streams have poor in-stream habitat structure, often typified by indistinct and shallow low-flow channels within a much larger and unstable storm channel. The goal is to restore in-stream habitat structure that has been blown out by erosive floods. Key restoration elements include creating pools and riffles, confining and deepening the low-flow channels, and providing greater structural complexity across the streambed. Typical tools include installation of log check dams, stone wing deflectors, and boulder clusters along the stream channel.

Case Study: Urban Stream Restoration in the Waukegan River, Illinois

An urban stream restoration project is underway in the Waukegan River in Illinois to repair channel instabilty caused by runoff from impervious surfaces and lack of storm water controls. The project uses biotechnical bank restoration to stabilize streambanks and low stone weirs to restore pool and riffle sequences. A habitat monitoring design was also used to document water quality changes. The project has improved biological diversity through pool and riffle restoration, yet it did not significantly improve stream fisheries. For more information about the project, refer to *Section 319 Nonpoint Source National Monitoring Program: Successes and Recommendations* (NCSU, 2000).

e. Reestablish riparian cover

Riparian cover is an essential component of the urban stream ecosystem. It stabilizes banks, provides large woody debris and detritus, and shades the stream, reducing water temperatures. Therefore, this tool involves reestablishing the riparian cover plant community along the stream network. This can entail active reforestation of native species, removal of exotic species, or changes in mowing operations to allow gradual succession. It is often essential that the riparian corridor be protected by an urban stream buffer (see Management Measure 3).

f. Protect critical stream substrates

A stable, heterogeneous streambed is often a critical requirement for fish spawning and secondary production by aquatic insects. The bed of an urban stream, however, is often highly unstable and clogged by deposits of fine sediment. It is often necessary to apply tools to restore the quality of stream substrates at points along the stream channel. Often, the energy of urban storm water can be used to create cleaner substrates through the use of flow concentrators and other manufactured devices. (See Management Measure 5 for more information about these practices.) If thick deposits of sediment have accumulated on the bed, mechanical sediment removal might be needed.

g. Allow for recolonization of the stream community

It might be difficult to reestablish the fish community in an urban stream if downstream fish barriers prevent natural recolonization. In these instances it is important to seek the judgment of a fishery biologist to determine whether downstream fish barriers exist, whether they can be removed, or whether selective stocking of native fish is needed to recolonize the stream reach.

h. Daylight streams

Daylighting involves returning a stream that has been buried in a pipe or culvert to the surface. In many cases the stream can be restored to its original channel, but sometimes a new channel must be engineered. Flow control structures and flood control measures can be incorporated into the design of the new or restored channel. Planting, restoring, and maintaining streambank vegetation and providing a diversity of in-stream habitat for submerged aquatic vegetation, fish, and aquatic insects are important aspects of the stream restoration project.

Daylighting typically requires a large capital investment for acquiring permits, engineering designs and expertise, equipment and labor for excavation, and plantings and labor to establish desirable stream morphology. Because communities are typically in favor of daylighting projects, many of these costs can be offset by recruiting sponsors such as property owners, community groups, housing associations, municipalities, environmental groups, and contractors. The benefits of a daylighting project for a particular stream reach should be carefully considered and weighed against the cost of the project to determine whether the project is worthwhile.

A source of information about daylighting is *Daylighting: New Life for Buried Streams*. In addition to summary findings, recommendations, and conclusions, the report also provides information about completed and proposed daylighting projects (Pinkham, 2000).

Case Study: Daylighting Jolly Giant Creek, Arcata, California

A classic example of daylighting is Arcata, California's Jolly Giant Creek (Pinkham, 1998). The daylighting and stream restoration project was initiated in 1991 by a high school biology teacher, Lewis Armin-Hoiland, and Humboldt State University students Melissa Bukosky and Tom Hagberg. They started the project initially to provide environmental education to high school and college students on stream ecology and restoration, but Bukosky continued to gather data and design a new channel and restoration plan for the creek.

The Redwood Community Action Agency, a nonprofit regional development organization, obtained a grant from the California Department of Water Resources Urban Streams Restoration Program. Other funding sources included U.S. Fish and Wildlife Service Challenge Cost-Share, the city of Arcata, and donations from a local heavy equipment contractor and the National Tree Trust. A substantial amount of volunteer labor was used for revegetation and to conduct assessment and monitoring. Funding for the project totaled $120,000.

The first phase of the stream restoration project included removing nearly 100 feet of culvert; installing a sedimentation basin, a ⅓-acre pond, and 75 feet of new stream channel; providing bank stabilization and flow control measures; and rerouting the stream through an older dry channel with existing riparian vegetation. The second phase involved creating a new channel within the old, wider channel at an abandoned mill site; creating berms around part of the property; restoring more than 400 feet of the Jolly Giant Creek; and providing a seasonal wetland and wet weather detention pond with substantial runoff storage capacity.

For more information contact Richard Pinkham, Senior Research Associate, Rocky Mountain Institute, 1739 Snowmass Creek Road, Snowmass, CO 81654; telephone 970-927-3807; e-mail rpinkham@rmi.org.

5. Preserve, Enhance, or Establish Buffers

Stream buffers might be present as part of previous development, but it is unlikely that existing buffers were established or maintained to maximize pollutant removal. As the intensity of surrounding development increases, runoff and pollutant loads increase and can result in damage to the buffer. Also, if the buffer is not protected from disturbance or excessive traffic, it can deteriorate over time. Buffers offer several environmental benefits, including improving soil and water quality, stabilizing stream banks, decreasing flood severity, replenishing ground water supply, and improving wildlife habitat (Schultz et al., 1996). Some steps that can be taken to preserve or enhance existing buffers include

- Delineating buffer boundaries and establishing management zones within the buffer (streamside, middle, and upland zones).
- Developing vegetative and use strategies within these zones.
- Establishing provisions for buffer crossings.
- Integrating structural runoff management practices where appropriate to protect the buffers and to augment their performance.
- Developing buffer education and awareness programs.

A buffer can be established in the area between the stream and existing development when buildings are set back from the stream to prevent damage from flooding. These areas can be mapped and buffer boundaries established based on runoff and pollutant loadings. In some cases, impervious surfaces in the buffer need to be removed or parts of the buffer regraded to ensure maximum pollutant removal efficiency. The buffers are then divided into three zones—the streamside, middle, and upland zones—that contain different types of vegetation and accomplish pollutant removal in different ways (Herson-Jones et al., 1995). Design considerations for stream buffers are discussed in more detail in Management Measure 3.

6. Revitalize Urban Areas

a. Encourage infill development

Infill development is a tool planners use to encourage siting of new development in unused lands in existing urban areas. Infill development usually works in tandem with community redevelopment initiatives to foster revitalization of existing neighborhoods. Infill and redevelopment can be employed in either large or small projects. One impediment to more widespread implementation of infill projects is the existing condition of a potential redevelopment site in terms of environmental constraints. The restrictive nature of many land use regulations and pressing social and economic issues might also impede implementation. Faced with these constraints, local governments often need to modify local zoning or building codes to make infill development and redevelopment more inviting to developers. Experience has shown that citizen involvement has often been a catalyst for leveraging funding or revising codes for this type of renewal.

Case Study: Examples of Infill Development

Wilson et al. (1998), in their book entitled *Green Development: Integrating Ecology and Real Estate*, described several infill development projects in California that are designed to revitalize the neighborhood, encourage the use of public transportation, and capitalize on proximity to complementary land uses. For example, the San Francisco Main Library was built on an infill site in San Francisco's Civic Center district that previously had been a parking lot with a small municipal building. The library contributes to the character of the neighborhood. It is located adjacent to a Bay Area Regional Transit station, is easily accessible by foot or bus, and has bike racks to encourage staff and patrons to use forms of transportation other than private automobiles.

Another infill project, in Pasadena, California, is the Holly Street Village Apartments, which combine "mixed-use, mixed-income housing, historic preservation, and attractive site planning and architecture." The complex is located between Pasadena's Civic Center and its revitalized historic commercial district. The apartment complex itself consists of 358 units of new housing, 16 loft apartments adapted from the historic former police headquarters building, and ground-floor retail units. A light rail station is soon to be built near the complex. This project's success has attracted further residential development projects in the area.

Both of these projects, and infill projects in general, take advantage of existing infrastructure and increase tax revenues without substantially increasing municipal expenses. Although development density increases with infill development, quality of life will not be compromised if the new development is properly planned to complement the existing neighborhood.

b. Assess previously contaminated soils to promote redevelopment

In many urbanized areas, changes in development patterns and economic decline have resulted in deterioration or abandonment of industrial and commercial sites. These dormant, sometimes contaminated sites contribute to water quality degradation by contaminating runoff and ground water and by contributing to imperviousness in the watershed. These underused urban areas can be assessed for contamination, remediated, and redeveloped in an environmentally friendly manner to improve surface and ground water quality. An additional benefit is improvement of the socioeconomic climate of the neighborhood. Redevelopment plans can include features such as disconnected impervious areas, infiltration areas, biofiltration systems, and on-site runoff storage to ensure that runoff leaving the site more closely mimics predevelopment water quality and quantity conditions.

EPA's Office of Solid Waste and Emergency Response has a brownfields initiative that encourages the redevelopment of abandoned, lightly contaminated industrial sites in economically stressed communities (USEPA, 1999). The program provides funding and guidance to help communities locate potential brownfields redevelopment sites, to perform soil and ground water assessments to determine the nature and extent of contamination, and to promote environmental cleanup and redevelopment of these sites. The program includes tax incentives for potential redevelopers and waivers of liability for past contamination. It encourages federal, state, and local coordination of enforcement activities and stakeholder and community involvement to identify and plan new uses for brownfields to promote environmental health and safety, environmental justice, and economic growth for economically depressed communities.

The brownfields initiative has several advantages for communities with underused, potentially contaminated sites. It provides a catalyst for assessment of urban areas for sites in need of cleanup and redevelopment to improve the community's surface and ground water quality, quality of life, and property values. Redeveloping properties that have already been disturbed helps to prevent development of greenfields—undeveloped suburban areas—and slows the growth of imperviousness in the outskirts of urban areas. It also provides an incentive for communities to alleviate soil and ground water contamination and to convert abandoned, eyesore lands to viable businesses, recreational facilities, or other uses.

In 2002, the brownfields program was expanded and strengthened through ratification of the Small Business Liability Relief and Brownfields Revitalization Act (see *www.epa.gov/brownfields/sblrbra.htm* for more information). More information about EPA's Brownfields Initiative is available at *www.epa.gov/brownfields*.

Information Resources

The *Anacostia Watershed Restoration Progress and Conditions Report 1990-1997* summarizes accomplishments and ongoing projects of the Anacostia Watershed Resoration Committee as they relate to their six restoration goals. In addition, the report provides recommendations to the Committee for future actions to sustain and further promote the restoration effort.

The Federal Interagency Stream Restoration Working Group (2000), which is a cooperation of 15 federal agencies including EPA and USDA, published *Stream Corridor Restoration: Principles, Processes, and Practices*. This document covers background information about stream corridors, including processes, characteristics, and disturbances; development of a stream corridor restoration plan; and application of restoration principles to stream corridor projects. *Stream Corridor Restoration: Principles, Processes, and Practices* can be purchased or downloaded in PDF format at *www.usda.gov/stream_restoration/newgra.html*.

Riparian Buffer Strategies for Urban Watersheds (Herson-Jones et al., 1995) provides guidance on riparian buffer programs used to mitigate the impact of urban areas on nearby streams. The document uses the results of a national survey of riparian buffer programs as well as a comprehensive review of riparian buffer literature to make recommendations on buffer design. It also analyzes buffer pollutant removal potential and pollution prevention techniques via chemical, biological, and physical processes. It is available for purchase at *www.mwcog.org/ic/95703.html*.

The Save Our Streams Program is a national watershed education and outreach program by the Izaak Walton League (no date). They offer many stream-related resources, including information on stream projects and publications such as *A Citizen's Streambank Restoration Handbook*. The Save Our Streams Program can be reached by e-mail at sos@iwla.org, by calling 1-800-BUG-IWLA, or by visiting the web site at *www.iwla.org/sos*.

The Natural Resources Conservation Service National Conservation Buffer Initiative web site (*www.nhq.nrcs.usda.gov/CCS/Buffers.html*) contains information about buffers, links to technology information, and buffer initiative contacts (NRCS, no date).

Urban Restoration: A Video Tour of Ecological Restoration Techniques (Riley, 1998b) is a video tour of six urban stream restoration sites. It includes background information on how the projects were funded and organized with community involvement and the history and principles of restoration. Additionally, examples are presented of stream restoration in very urbanized areas, recreating stream shapes and meanders, creek daylighting, soil bioengineering, and ecological flood control projects. A companion to the video is *Restoring Streams in Cities: A Guide for Planners, Policymakers, and Citizens* (Riley, 1998a). This book includes detailed information on all relevant components of stream restoration projects, from historical background to hands-on techniques. The book and video can be purchased at *www.noltemedia.com/nm/urbanstream/index2.html*.

EPA and the LID Center conducted a literature review of LID studies to assess the state of knowledge about LID practices (USEPA, 2000c). The final report contains a brief overview of LID principles and programmatic issues such as use, ownership, and cost. The heart of the document is a summary of the information available regarding the pollutant removal effectiveness of the most common LID practices. The report is available for download in PDF format at *www.epa.gov/owow/nps/lidlit.html*. This page also contains links to low-impact development fact sheets on bioretention, vegetated roof covers, permeable pavements, and street surface storage of runoff.

EPA's River Corridor and Wetland Restoration web site contains general information about restoration and its benefits, a list of restoration guiding principles that cover the entire life of a restoration project from early planning to post-implementation monitoring, restoration project descriptions, and links to other restoration resources. The site is located at *www.epa.gov/owow/wetlands/restore*.

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